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Drive system for an off-road utility vehicle

The invention relates to a drive system for an off-road utility vehicle according to the preamble of patent claim 1.

Drive systems of the type mentioned at the beginning are known, in particular from the series-produced UNIMOG utility vehicles of the applicant, in which a drive engine, via an external clutch, drives a main speed-change gearbox which has a plurality of gears, in particular four gears, and to which a two-stage range group in the form of an epicyclic set is assigned in series in the power flow. A drive path leads from the main speed-change gearbox to a transfer gearbox which has a front axle output and a rear axle output. A permanent drive connection between the main speed-change gearbox and the axle drive of the rear axle is created via the rear axle output. In a first, extreme off-road UNIMOG model, a manually controllable axle engagement clutch in the form of a dog clutch is operatively provided in the transfer gearbox between rear axle output and front axle output, via which axle engagement clutch the axle drive of the front axle can be connected through to the axle drive of the rear axle. In a second UNIMOG model, which is conceived as an implement carrier, has permanent all-wheel drive and is usually used on paved roads, a longitudinal differential is operatively provided in the transfer gearbox between rear axle output and front axle output in order to compensate for the speed differences between front axle and rear axle(s) when negotiating tight curves, this longitudinal differential ideally bringing about uniform distribution of the drive torque to the front and rear axles. In this all-wheel drive,

due to the permanent engagement of all the wheels, overloading of the rear axle(s) is in principle avoided, even in the case of difficult traction on an adherent roadway, without this depending on the driver. A positive, manually controllable differential lock makes it possible to achieve better traction in this all-wheel drive. In both UNIMOG models, the transverse differentials of the axle drives of front axle and rear axle can likewise be locked by manually controllable positive differential locks.

The advantages of the UNIMOG model with engageable front wheel axle lie essentially in the specific engagement option with corresponding usage profiles (e.g. tractor or off-road use) and in a "clear drive train state" by deliberate engagement of the front axle and the differential locks of the transverse differentials. The experience gained over several decades with this UNIMOG model has shown that the advantages of this simple and easily comprehensible method of engaging the front axle prevail in most applications. These many years of experience also show that a foresighted driving technique and estimation of the ground conditions both in easy terrain and especially in difficult terrain have proved to be substantially more effective and reliable than all the hitherto known open-loop and closed-loop control systems. These systems recognize difficult roadway subgrades only when the vehicle has already experienced a loss of speed or a loss of the propulsion, whereas the driver already estimates the situation in advance and, if appropriate, can engage the front wheel drive. However, there is the risk in the case of difficult traction that the rear-axle drive components will be subjected to excessive stress at high adhesion coefficients if the front axle is not engaged due to inattentiveness on the part of the driver.

Independently thereof, DE 30 34 229 A1 has disclosed a drive system which is not of the generic type for a motor vehicle (passenger car) with front wheel drive via an automatic gearbox and with a torque converter connected to the crankshaft of the engine of the motor vehicle, in which drive system the automatic gearbox is connected to the turbine shaft of the torque converter and has an epicyclic train and a plurality of fluid-medium-actuated devices for producing various operating states and also a final reduction gear for transmitting the power output of the automatic gearbox to the front wheels. In this drive system, a clutch device is provided for transmitting the power output of the automatic gearbox to the rear wheels, this clutch device containing a fluid-medium-actuated multiplate clutch. Since, for changing over to four wheel drive, it is considered to be too complicated to first of all bring the selector lever of the automatic gearbox into the neutral position in order to be able to actuate a second lever for the engagement of the clutch device for the engagement of the rear axle, it is desirable for the front wheel drive to be shifted automatically to the four wheel drive as a function of the drive state. On the whole, the aim in the case of this drive system is to provide an automatic gearbox having a multiplate clutch operated by pressure oil, the shifting between the front wheel drive and the four wheel drive being executed in accordance with the various drive conditions of the motor vehicle, and it also being possible for the multiplate clutch to be actuated as a function of the drive conditions of the vehicle by pressure oil used in the automatic gearbox. Accordingly, in this drive system, a pressure-oil control device for actuating the flow-medium-actuated devices of the automatic gearbox contains a pressure

control valve for producing a line pressure in accordance with the operating state of the engine and a changeover valve for connecting a line for the line pressure to the flow-medium-actuated multiplate clutch. Furthermore, in this drive system, a manual actuating device for actuating the changeover valve is provided in order to apply the line pressure to the flow-medium-actuated multiplate clutch.

EP 0 076 148 B1 discloses a further drive system which is not of the generic type for a motor vehicle (passenger car) with a front wheel drive and with an engine and a device for controlling the drive torque, in which drive system a transmission for the effective power transmission from the engine to the front wheels, a friction clutch for the power transmission to the rear wheels and a clutch-actuation device for engaging and disengaging the friction clutch are provided. In this known drive system, it is assumed that the friction clutch can generally be operated with slip which can be adjusted as a function of the steering angle in order to permit, when negotiating curves, the higher speed of the front wheels passing through a larger curve radius than the rear wheels, and furthermore the aim is to be able to set the slip of the friction clutch as a function of further parameters of the drive state, such as the slip of the vehicle wheels. For this purpose, in this known drive system, provision is also made for the clutch-actuation device to have a selecting device which optionally permits partial engagement, engagement which is more intense than the partial engagement, or disengagement of the friction clutch, and for the regulating device to have a slip-detection device for detecting the slip of the wheels, a load-detection device for detecting the engine load, and a control means which, as a function

of the signals from the slip-detection device and the load-detection device, actuates the selecting device in such a way that the more intense engagement of the friction clutch is effected during heavy loading and when the wheels are slipping.

Finally, DE 38 38 709 A1 discloses a further drive system which is not of the generic type for a motor vehicle with automatic changeover from two wheel drive to four wheel drive as a function of the slip of the two permanently driven wheels. In this drive system which is not of the generic type, the disadvantages of a conventional method of detecting a degree of slip of the permanently driven wheels which calls for the four wheel drive are to be avoided, which disadvantages can be seen in the fact that, in the operating state of the four wheel drive, mechanical separation of the engaged wheels from the drive is necessary at time intervals quickly following one another. This is said to be achieved by the speed difference of the two permanently driven wheels being permanently formed by means of two sensors assigned to one each of said wheels and by this speed difference being fed to a computer which has stored a respective vehicle-specific characteristic speed difference for the two wheel drive and the four wheel drive and compares the fed speed difference as a function of the respective drive state with one of these characteristic speed differences, in which case the drive, by means of an actuator connected in series with the computer, can be changed over from two wheel drive to four wheel drive, or vice versa, if the comparison shows that the characteristic speed difference assigned to the two wheel drive is exceeded or that the speed difference is less than the characteristic speed difference assigned to the four wheel drive.

Against this background, the object of the present invention is essentially to be seen in the fact that, in a drive system of the generic type for an off-road motor vehicle, in which drive system the engagement of the front axle is generally controlled manually by the driver, the risk of the rear axle being subjected to excessive stress in the case of difficult traction at high adhesion coefficients and of its service life being reduced as a result, because the front axle has not been engaged due to inattentiveness on the part of the driver, is countered.

The object explained is advantageously achieved according to the invention by the features of patent claim 1.

In the case of the drive system according to the invention, the advantages of the manual engagement of the all-wheel drive by engaging the front axle during off-road use are ensured and excessive stresses of the rear axle(s) are avoided, which otherwise, due to the inattentiveness on the part of the driver, may occur with a purely manual method of engaging the front axle in the case of difficult traction on an adherent roadway. By avoiding these disadvantages, a permanent all-wheel drive with longitudinal differential can be dispensed with in many applications. This means that, in the previous all-wheel versions with longitudinal differential, the longitudinal differential in the transfer gearbox can be dispensed with.

In the drive system according to the invention, the propulsion in normal operation is effected only via the rear axle(s). If greater traction is required or in the case of roadway surfaces having low adhesion

coefficients, the front axle is engaged manually by the driver or, in an embodiment as claimed in patent claim 8, with appropriate provision of slip-dependent automatic closed-loop and/or open-loop control systems. Therefore no longitudinal differential is required between front axle and rear axle(s). The driving/mechanical advantages of such a drive system according to the invention with a generally manually engageable front axle consist in the clearly defined operating states of the drive train and of the resulting clearly defined traction and driving behavior.

In the drive system according to the invention, the engagement strategy with regard to the front axle and the differential locks of the axle differentials is formed in two different respects depending on the drive state and adhesion coefficients in such a way that, on the one hand, during traction on an adherent roadway with high adhesion coefficients, the front axle is automatically engaged as a function of the engine torque. In an embodiment according to patent claim 2, the engagement is advantageously effected only above a threshold value of an engine load, this threshold value being related to a defined fraction of the maximum engine torque and taking into account the instantaneous transmission ratio. Depending on the vehicle type or model, this defined fraction, according to patent claim 3, may lie within a value range of between 60% and 90% of the maximum engine torque and, according to patent claim 4, may preferably be about 75%.
In an advantageous embodiment of the drive system according to the invention according to patent claim 5, this engine load, for the effective engagement of the front wheel drive, must have exceeded for a certain time the limit defined by the threshold value in order

to ensure that the engine load involves not only a brief torque peak but also a quasistatic load case, e.g. traction on a gradient. On the other hand, in the drive system according to the invention, in construction site operation, in winter service and during off-road use, in order to increase the traction and driving safety with low adhesion coefficients, driver-determined manual engagement and disengagement is provided in steps in such a way that the front axle is engaged in a first step if the motor vehicle is being used on a construction site, in winter service or during off-road use. This drive state is indicated to the driver by illumination of a single warning triangle in an information display. In a second step, the axle differentials of the rear axles can be locked, e.g. if the motor vehicle is being used in off-road operation and the adhesion coefficients are low. In this case, acceptable steerability is still provided for. This drive state is indicated to the driver by the illumination of two warning triangles in the information display. Finally, in a third step, the axle differentials of the front axle and of the rear axles can be locked, so that maximum traction is provided for. This drive state is selected by the driver if the vehicle is being used in off-road operation, in difficult terrain or on a subgrade covered with mud and is indicated by the illumination of three warning triangles in the information display.

In the drive system according to the invention, an electronic control unit, in a permanent control state, checks the load-dependent need for automatic engagement of the front axle. According to patent claim 6, this function can be overridden at any time by the driver, that is to say it can be manually disengaged.

According to patent claim 7, in the drive system according to the invention, if the motor vehicle is in all-wheel operation due to the engaged front axle, an electronic control unit, in a permanent control state, carries out a further requisite check as to whether the operation of a closed-loop and/or open-loop control system influencing the driving state, such as ABS, ADM (automatic drive train management), ESP (electronic stability program) or ESC (engine speed control), is impaired or event prevented by the all-wheel drive. For this case, the control unit automatically disengages the front axle.

In the drive system according to the invention, in the embodiment according to patent claim 8, when applied to certain vehicle types, for example fire engines, the slip-dependent (longitudinal and transverse slip) engagement strategies known from the passenger cars and off-road vehicles can be superimposed on the load-dependent engagement strategy for the front axle. In connection with such engagement strategies, DE 43 27 507 C2 discloses a method for the automatic control of the clutches for activating at least one axle transverse lock and a longitudinal lock or the engagement of the front wheel drive in the drive train of an off-road vehicle with all-wheel drive, in which method slip signals, based on wheel speed signals, are formed and compared with threshold values and thus control signals are generated for the clutches. In this known method, the procedure is such that a separate control module is provided in each case for each individual clutch, and this control module generates control signals for the specific clutch, that the control modules of the clutch of the at least one axle transverse lock also deliver control signals for the clutch of the longitudinal lock or for the engagement

of the front axle before they activate the specific clutch, and that the slip signals are slip summation signals which are separately formed by integration of the wheel speed differences assigned to the at least one axle lock, the longitudinal lock or the engagement of the front wheel drive and are compared with stepped slip summation threshold values, by means of which the sequence and the reaction time of the locking of the locks or of the engagement of the front wheel drive is controlled.

The invention is described in more detail below with reference to an exemplary embodiment schematically shown in the drawing, in which:

fig. 1 shows a drive system according to the invention illustrated like a block diagram, and

fig. 2 shows a signal flow diagram for controlling the two drive states "rear-axle drive" and "all-wheel drive".

With reference first of all to figure 1, an off-road utility vehicle is driven from a drive engine 3 via a speed-change gearbox 16 which has a four-stage basic gearbox 4, to which a two-stage range-change gearbox 7, for example in the form of an epicyclic set, is assigned in series in the power flow. The basic gearbox 4 is in drive connection with the drive engine 3 via an external clutch 8. The eight gears of the speed-change gearbox 16 which are obtained by means of the range-change gearbox 7 are selected by a manual selector device 9, if need be with power assistance, this manual selector device 9 having a position sensor 10 which generates a signal 11 for a gear display and a transmission ratio relating to this, said signal 11

being directed as input signal to an electronic control unit 12. The output shaft of the speed-change gearbox 16 is in drive connection with a transfer gearbox 13 which has a gearbox output 14 assigned to a rear axle 5 and a gearbox output 15 assigned to a front axle 6.

The gearbox output 14 is constantly in drive connection with both the output shaft of the speed-change gearbox 16 and an axle differential (transverse differential) 18 of the rear axle 5. The axle differential 18 can be locked by a positive, engaging and disengaging differential lock 19, which can be actuated by a motor-operated locking actuator 20 which can be activated via the control unit 12.

The gearbox output 15 for the front axle 6 is connected to the gearbox output 14 by an engaging and disengaging axle engagement clutch AZK, which is actuated by a motor-operated clutch actuator 17 which can be activated via the control unit 12. Furthermore, the gearbox output 15 is constantly in drive connection with an axle differential (transverse differential) 21 of the front axle 6, and this axle differential 21 can be locked by a positive, engaging and disengaging differential lock 22, which can be actuated by a motor-operated locking actuator 23 which can be activated via the control unit 12, in particular in a slip-controlled manner, or by the driver.

The electronic control unit 12 is fed by various information specific to the vehicle or vehicle state in the form of input signals, inter alia

- an input signal 24, dependent on the instantaneous engine load M_m, of a torque-sensing device 25,

- the input signal 11 corresponding to the engaged gear of the speed-change gearbox 16 and a relevant transmission ratio i_G,
- an input signal 26, which can be triggered by the driver by means of a pushbutton 27, for the engagement of the front axle 6 by activation of the axle engagement clutch AZK,
- an input signal 28, which can be triggered by the driver by means of a pushbutton 29, for locking the axle differential 18 of the rear axle 5 by activation of the differential lock 19,
- an input signal 30, which can be triggered by the driver by means of a pushbutton 1, for locking the axle differential 21 of the front axle 6 by activation of the differential lock 22,
- an input signal 32, generated by a speed sensor 33, for the speed of the one rear wheel of the rear axle 5,
- an input signal 34, generated by a speed sensor 35, for the speed of the other rear wheel of the rear axle 5,
- an input signal 36 indicating the operating state of the ABS, and
- a the operating state of a further closed-loop and/or open-loop control system influencing the driving state, such as ADM (automatic drive train management), ESP (electronic stability program) or ESC (control of the engine speed to a constant speed value).

Finally, as indicated at 38, a threshold value SW for a critical engine load M, which is based, for example, on an engine torque M_m equal to about 75% of the maximum engine torque and takes into account the instantaneous transmission ratio i_G, and, as indicated at 39, a delay time T_V assigned to the threshold valve SW are filed in

the control unit 12. At an engine load M < SW, the ***automatic*** load-dependent engagement of the front axle 6 is locked. Automatic load-dependent engagement of the front axle 6 is only effected when an engine load M > threshold value SW is applied beyond the delay time T_V and overriding manually or by closed-loop and/or open-loop control systems such as ABS or the like which influence the driving state is not effective.

The functioning of the drive system of figure 1 is obtained from the signal flow diagram of figure 2 as follows:

By a starting step 40 being activated, this starting step 40 triggers a test step 41 by means of an output signal 40a, and this test step 41 establishes whether the front axle 6 is engaged. If this is the case, the test step 41 transmits a disengagement signal 41a to the actuator 17 of the axle engagement clutch AZK, so that the latter is brought into its disengaged position 17a for disengaging the axle engagement clutch AZK. Otherwise, if the front axle 6 is therefore not engaged, the test step 41 switches an output signal 41b to a comparison step 42 and to two test steps 46 and 47.

The triggering of the one test step 46 establishes whether the pushbutton 27 is depressed for manual engagement of the front axle 6. If this is the case, the clutch actuator 17 receives an engagement signal 46a from the test step 46, by means of which engagement signal 46a the clutch actuator 17, irrespective of how the further sequence proceeds from the comparison step 42, is brought into its position 17e for the engagement of the front axle 6. Otherwise, by delivery of an output signal 46b, the test step 46 is put into a

waiting loop until the next working cycle, which then triggers the test step 46 again.

The triggering of the other test step 47, with reference to the speed signals 32 and 34, establishes whether the rear axle 5 is in the slip state. If this is the case, the clutch actuator 17 receives an engagement signal 47a from the test step 47, by means of which engagement signal 47a the clutch actuator 17, irrespective of how the further sequence proceeds from the comparison step 42, is brought into its position 17e for the engagement of the front axle 6. Otherwise, by delivery of an output signal 47b, the test step 47 is put into a waiting loop until the next working cycle, which then triggers the test step 47 again.

The triggering of the comparison step 42 establishes whether the instantaneous engine load M, which, from the combination of the engine torque M_m and the current transmission ratio i_G, is obtained as $M = M_m \times i_G$, is greater than the threshold value SW. If this is the case, the comparison step 42 generates an output signal 42b for triggering a test step 43. Otherwise, the comparison step 42 delivers a disengagement signal 42a for the clutch actuator 17 and for setting a waiting loop, so that the comparison step 42 is triggered again during the next working cycle.

In the test step 43, it is established whether the delay time T_V has elapsed. In this case, the test step 43 generates an output signal 43b for triggering a further test step 44. Otherwise, the test step 43 delivers a disengagement signal 43a for the clutch actuator 17 and for setting a waiting loop, so that the test step 43 is triggered again during the next working cycle.

In the test step 44, it is established whether auxiliary drives NA or power take-off shafts or the like are in operation. If this is not the case, the test step 44 generates an output signal 44b for triggering a last test step 45. However, if a power take-off shaft, for example, is in operation, the test step 44 delivers a disengagement signal 44a for the clutch actuator 17 and for setting a waiting loop, so that the test step 44 is triggered again during the next working cycle.

It is established by means of the test step 45 whether the ABS is activated. If the ABS is not activated for controlling the brake forces, the test step 45 generates an output signal 45b for applying to the clutch actuator 17, so that the latter is brought into its position 17e for engaging the AZK and thus for the engagement of the front axle 6. On the other hand, should the ABS be functioning and regulating the brake forces, the test step 45 delivers a disengagement signal 45a for the clutch actuator 17 and for setting a waiting loop, so that the test step 45 is triggered again during the next working cycle.

The priority control steps required for the abovementioned overriding of the functions "engagement" and "disengagement" with regard to the front axle by the driver or by closed-loop and open-loop control systems specific to the vehicle are no longer shown in order to make it easier to understand the drive system.